(11)Publication number : 2003-054730

(43)Date of publication of application : 26.02.2003

(51)Int.CI. B65G 33/14

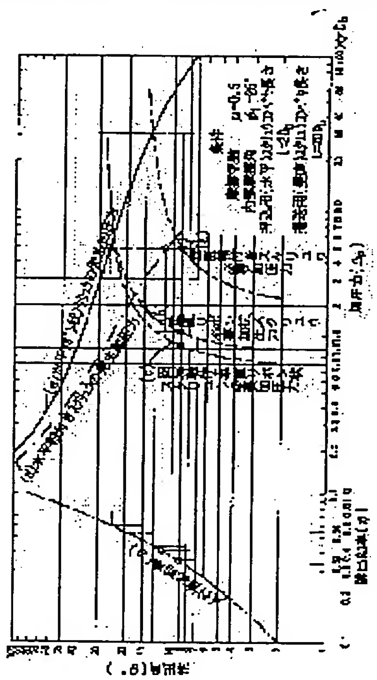
B65G 33/26

(21)Application number : 2001-241474 (71)Applicant : HITACHI ZOSEN CORP

(22)Date of filing : 09.08.2001

(72)Inventor : YOSHIKAWA TADAO

(54) METHOD FOR DESIGNING SCREW TYPE CONVEYOR



(57)Abstract:

PROBLEM TO BE SOLVED: To provide a method for designing a screw type conveyor having a high conveying efficiency.

SOLUTION: The method for designing the conveyor having a screw conveyor for lifting the subject to be conveyed and a pushing screw conveyor for pushing the subject to be conveyed into the lifting conveyor includes determining a necessary pressure curve showing the necessary pressure within a lifting cylindrical casing and a generated pressure curve showing the pressure generated within a pushing cylinder casing, from an equation showing pressure at a certain position of the subject to be conveyed which is packed in the cylindrical casings; then determining, using a discharge efficiency curve, a discharge angle which corresponds to design discharge efficiency; determining the pressure needed for lifting, based on the necessary pressure curve which matches the discharge angle; generating the generated pressure equal to or greater than the required pressure in the pushing conveyor; and determining the rotation speed of the screw of each of the lifting and pushing conveyors based on the discharge efficiency, design discharge efficiency, and design amount of conveyance of the pushing conveyor

matched the generated pressure.

CLAIMS

[Claim(s)]

[Claim 1] The screw conveyor for a transfer by lifting which it comes to arrange free [rotation in tubed casing toward which the screw for a transfer by lifting inclined], It has the screw conveyor for pushing which it comes to arrange free [rotation in tubed casing by which the screw for pushing has been arranged almost horizontally]. With and this screw conveyor for pushing It is the design approach of the screw-type transport device which were and transported it made to lift after it pushed in the conveyed object and the conveyed object had been full within the above-mentioned inclination tubed casing in the above-mentioned screw conveyor for a transfer by lifting. The following formula showing the pressure (PL) in the arbitration location of the conveyed object which it was full of within tubed casing obtained from keeping of the force in the direction of a revolving-shaft alignment of the screw in tubed casing, and keeping of the force in the rotation circumferencial direction of a screw By a conveyed object being full and deforming using the conditions of being PL>=0, within tubed casing While asking for the need pressurization curve which shows the relation between a drained angle of repose theta and the need welding pressure within inclination tubed casing, and the generating pressurization curve which shows the relation between a drained angle of repose theta and the generating welding pressure in level tubed casing While asking for the discharge efficiency curve which shows the relation between the above-mentioned drained angle of repose theta and the discharge effectiveness eta and asking for the drained angle of repose corresponding to predetermined discharge effectiveness based on the above-mentioned discharge efficiency curve While asking for welding pressure required for a transfer by lifting from the above-mentioned need pressurization curve according to this drained angle of repose and making it generate the generating welding pressure more than this welding pressure with the above-mentioned screw conveyor for pushing It responds to this generating welding pressure. From the above-mentioned generating pressurization curve and a discharge efficiency curve The design approach of the screw-type transport device characterized by searching for the discharge effectiveness in the screw conveyor for pushing concerned, and asking for the rotational frequency of each screw in the above-mentioned screw conveyor for a transfer by lifting, and the screw conveyor for pushing from the relation between each discharge effectiveness and the amount of design conveyances further.

[Equation 1]

However, the semantics of the notation in the above-mentioned formula is as follows.
C: constant = (Db-2H) -- /DbDb:screw outer-diameter E:constant = (Db-H) -- /DbH:screw channel depth K:coefficient-of-lateral-pressure = (1-sin2phii/1+sin2phii)
L: pressure e:screw wing thickness t:screw pitch alphab: in the pressure PO:conveyor inlet port in screw conveyor effective length PL:conveyor die-length L -- angle-of-torsion theta:drained-angle-of-repose phi: of the angle-of-torsion alphar:screw shaft diameter of the angle-of-torsion alpham:screw pitch diameter of a screw outer diameter -- express coefficient of friction of the object of the object of a screw conveyor conveyed [tilt-angle mub:], and a tubed casing inside conveyed [coefficient-of-friction mus:], and a screw wing side, respectively.

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the design approach of a screw-type transport device.
[0002]
[Description of the Prior Art] While a screw conveyor is used when ****(ing) the earth and sand discharged from tunnel excavation construction of large depth, the ore in a boathouse, a particulate matter (grain is included), etc. for example, conveyance (transfer by lifting) is mostly performed in the direction of a vertical.
[0003] And in the case of the screw conveyor which performs conveyance on such a steep slope, conveyance was performed after the conveyed object had been pushed against the casing inside by the centrifugal force based on rotation of a screw wing.
[0004]
[Problem(s) to be Solved by the Invention] According to the screw conveyor mentioned above, the conveyed object had problems, like the noise at the time of operation is loud, in order for the screw itself to rotate at a high speed like for example, 500RPM, while a vertical plane will be mostly gone up after having been pushed against a casing inside by the centrifugal force, therefore the rate of fullness within casing falls, and conveyance effectiveness worsens and wear of the conveyor itself progresses early.
[0005] Then, this invention aims at offering the design approach of a screw-type transport device with sufficient conveyance effectiveness.
[0006]
[Means for Solving the Problem] In order to solve the above-mentioned technical

problem, the design approach of the screw-type transport device of this invention The screw conveyor for a transfer by lifting which it comes to arrange free [rotation in tubed casing toward which the screw for a transfer by lifting inclined], It has the screw conveyor for pushing which it comes to arrange free [rotation in tubed casing by which the screw for pushing has been arranged almost horizontally]. With and this screw conveyor for pushing It is the design approach of the screw-type transport device which were and transported it made to lift after it pushed in the conveyed object and the conveyed object had been full within the above-mentioned inclination tubed casing in the above-mentioned screw conveyor for a transfer by lifting. The following formula showing the pressure (PL) in the arbitration location of the conveyed object which it was full of within tubed casing obtained from keeping of the force in the direction of a revolving-shaft alignment of the screw in tubed casing, and keeping of the force in the rotation circumferencial direction of a screw By a conveyed object being full and deforming using the conditions of being PL>=0, within tubed casing While asking for the need pressurization curve which shows the relation between a drained angle of repose theta and the need welding pressure within inclination tubed casing, and the generating pressurization curve which shows the relation between a drained angle of repose theta and the generating welding pressure in level tubed casing While asking for the discharge efficiency curve which shows the relation between the above-mentioned drained angle of repose theta and the discharge effectiveness eta and asking for the drained angle of repose corresponding to predetermined discharge effectiveness based on the above-mentioned discharge efficiency curve While asking for welding pressure required for a transfer by lifting from the above-mentioned need pressurization curve according to this drained angle of repose and making it generate the generating welding pressure more than this welding pressure with the above-mentioned screw conveyor for pushing It responds to this generating welding pressure. From the above-mentioned generating pressurization curve and a discharge efficiency curve It is the approach of searching for the discharge effectiveness in the screw conveyor for pushing concerned, and asking for the rotational frequency of each screw in the above-mentioned screw conveyor for a transfer by lifting, and the screw conveyor for pushing from the relation between each discharge effectiveness and the amount of design conveyances further.

[0007]

[Equation 2]

However, the semantics of the notation in the above-mentioned formula is as follows.
C: constant = (Db-2H) -- /DbDb:screw outer-diameter E:constant = (Db-H) -- /DbH:screw channel depth K:coefficient-of-lateral-pressure = (1-sin2phii/1+sin2phii)
L: pressure e:screw wing thickness t:screw pitch alphab: in the pressure PO:conveyor inlet port in screw conveyor effective length PL:conveyor die-length L -- angle-of-torsion theta:drained-angle-of-repose phi: of the angle-of-torsion alphar:screw shaft diameter of the angle-of-torsion alpham:screw pitch diameter of a screw outer diameter -- express coefficient of friction of the object of the object of a screw conveyor conveyed [tilt-angle mub:], and a tubed casing inside conveyed [coefficient-of-friction mus:], and a screw wing side, respectively.

[0008] According to the above-mentioned design approach, from the need pressurization curve in the screw obtained from the formula showing the pressure in tubed casing in the condition that the conveyed object was full While asking for the need welding pressure in the screw conveyor for a transfer by lifting corresponding to predetermined discharge effectiveness A transfer by lifting can be ensured [efficiently and] by asking for the engine speed of a screw from a discharge efficiency curve in the condition of having made the conveyed object full by making the screw conveyor for press driving the thrust exceeding this need welding pressure being also. That is, it can lift and transport that low-speed rotation is also, therefore conveyance effectiveness is good compared with the case where a conveyed object is lifted and transported in the condition with a clearance within tubed casing, and wear of machines can also obtain a screw-type transport device with little noise few.

[0009]

[Embodiment of the Invention] Hereafter, the design approach of the screw-type transport device in the gestalt of operation of this invention is explained based on drawing 1 - drawing 5 .

[0010] First, the outline configuration of the screw-type transport device concerning this

invention is explained based on drawing 1 and drawing 2 . This screw-type transport device 1 is formed in the material handling attachment 4 for unloading the particulate matter (an example of a conveyed object) J loaded in boathouse 2a of a cargo boat 2 in the hopper 3 for a reservoir in which it was prepared at Quaywall (land) G. It consists of a screw conveyor 5 for a transfer by lifting which is mostly arranged in the direction of a vertical and conveys a particulate matter J from a lower part to the upper part (henceforth a transfer by lifting), and a screw conveyor 6 for pushing for being arranged almost horizontally and pushing in a particulate matter in the lower part of the above-mentioned screw conveyor 5 for a transfer by lifting.

[0011] In addition, the gate type track frame 11 whose transit on the guide rail prepared in material handling attachment 4 along with the cargo boat 2 which came at Quaywall G was enabled, The girder material 12 installed on the cargo boat 2 which came alongside the quay from the quaywall while being prepared above this track frame 11, The screw conveyor 5 for a transfer by lifting supported by the supporter material (not shown) which hung from the point of this girder material 12, The collection machine 13 which is formed in the lower limit section of the above-mentioned supporter material, and collects the particulate matter J in boathouse 2a by two or more bucket 13a, The screw conveyor 6 for pushing for stuffing into the above-mentioned screw conveyor 5 for a transfer by lifting the particulate matter J collected by this collection machine 13, The band conveyor 14 which conveys horizontally the particulate matter J which has been arranged at the above-mentioned girder material 12, and was conveyed to the upper part by the screw conveyor 5 for a transfer by lifting on Quaywall G, It consists of chutes 15 for showing the hopper 3 for a reservoir to the particulate matter J conveyed on this band conveyor 14.

[0012] Next, the screw-type transport device 1 for conveying a particulate matter J is explained based on drawing 2 . In addition, although this screw-type transport device 1 consists of a screw conveyor 5 for a transfer by lifting, and a screw conveyor 6 for pushing, it explains the screw conveyor 5 for a transfer by lifting first.

[0013] Namely, this screw conveyor 5 for a transfer by lifting While being arranged free [rotation in the tubed casing 21 supported by supporter material in the direction of a vertical, and this tubed casing 21], a shank (It is also hereafter called a screw shaft) It consists of rotation driving gears 23 made to rotate the screw 22 for a transfer by lifting (for it to be the screw with a shaft) with which it comes to prepare wing section (henceforth screw wing) 22b in a periphery and this screw 22 for a transfer by lifting of 22a. In addition, in order to rotate a long screw, without being twisted so much so that drawing 2 may show, he is trying to make it rotate by three places. Of course, while the

rotation ring (not shown) which fixed on the periphery of the screw 22 for a transfer by lifting is prepared in the tubed casing 21 in each [these] rotation part respectively free [rotation], the rotation drive of these rotation rings is carried out by one set of a motor 26 through a drive shaft 24 and the gearing device 25. Of course, two or more sets of motors can be arranged on the way, it can be alike, respectively, without minding a drive shaft and a gearing device, and the screw for a transfer by lifting can also be rotated more.

[0014] Next, while the screw conveyor 6 for pushing is almost horizontal and is arranged The tubed casing 31 by which the front end section was connected to lower limit feed hopper 21a of the tubed casing 21 of the screw conveyor 5 for a transfer by lifting, and feed hopper 31a of a particulate matter was formed in the back end section, While being arranged free [rotation in this tubed casing 31], it consists of a screw 32 for pushing formed in the shape of [which does not have a shank] a ribbon, and a motor 33 made to rotate the rotation ring (not shown) in which this screw 32 for pushing was formed by that periphery through a gearing device.

[0015] Here, the configuration of a rotation **** rotation ring is briefly explained for each above-mentioned screws 22 and 32. While the configuration using this rotation ring makes the rotation ring which is predetermined width of face and was formed in the periphery of a screw wing in the shape of a circular ring fix, it supports this rotation ring free [rotation] to a tubed casing side, and it is made to make it rotate it with a motor through the ring wheel in which this rotation ring was prepared by that peripheral face.

[0016] By the way, as mentioned above, the summary of this invention is by applying a pressure to the conveyed object supplied in the lower part of the tubed casing 21 of the screw conveyor 5 for a transfer by lifting, and making it full [continue and] in [whole] the tubed casing 21 to offer [the equipment which can perform efficient and small conveyance in a low speed, i.e., the noise, and] especially the design approach.

[0017] It faces designing such a screw conveyor, an important thing is getting to know, the pressurization condition (it also being called ******), i.e., the pressure condition, of a conveyed object within tubed casing, and this invention person used to be made solve the pressure condition of a conveyed object theoretically, and to ask for the item (specification) of a screw conveyor there based on this formula while he draws the formula showing the pressure in the arbitration location in tubed casing.

[0018] How to draw the formula which asks for the pressure of the conveyed object which the screw was full of within tubed casing arranged free [rotation] hereafter is explained. Here, in order to generalize a screw format in order to generalize the

candidate for application as much as possible so that the conveyance direction can apply to the thing from a horizontal to a vertical and, it explains as a screw conveyor with a shaft, and applies to that to which frictional force acts between screw conveyors still like a particulate matter and a massive object as a conveyed object.

[0019] In addition, the next assumption is prepared in order to simplify a formula.

** The conveyed object in tubed casing (particulate matter) touches all fields.

** A pressure is the function of the die length (x) of the slot in a screw wing.

[0020] ** Coefficient of friction of a pressure of a conveyed object and the contact surface by the side of a screw conveyor covers an overall length independently and is fixed.

** The clearance between the outer diameter of a screw and tubed casing is disregarded.

[0021] ** The conveyed object in the slot in a screw wing moves as a plug.

Here, the notation used into the formula shown below is explained.

[Explanation of a notation]

C: Constant =(Db-2H)/DbDb-: screw outer-diameter Dm:screw pitch-diameter Dr:screw shaft diameter (bore diameter of a ribbon-like screw wing)

E: Constant = (Db-H)/DbH : screw channel depth K:coefficient-of-lateral-pressure = (1-sin2phii/1+sin2phii)

L: Screw conveyor effective length PL: Pressure POin conveyor die-length L : Pressure Rin a conveyor inlet port : Screw radius W: Effective width [of a screw wing] e: Screw wing thickness t: Screw pitch alphab: the bulk density eta of the object of the angle-of-torsion alphar:screw shaft diameter of the angle-of-torsion alpham:screw pitch diameter of a screw outer diameter conveyed [angle-of-torsion gamma:] -- internal frictional angle phi: of the object conveyed [:discharge effectiveness theta:drained-angle-of-repose phii:] -- the object of a screw conveyor conveyed [tilt-angle mub:], and a tubed casing inside -- coefficient of friction (rhob=tan-1microb) mus: Coefficient of friction of a conveyed object and a screw wing side (rhos=tan-1microsecond)

** a character b:screw outer diameter -- section fp:screw side-face.push side ff:screw side-face length -- side m:screw average (center) diameter r:screw root diameter drawing 3 shows the equilibrium of the static force of acting on a part for one pitch of the wing section 42 in a screw 41, i.e., the minute part of the conveyed object it was [object] full of the slot 43 of a screw wing.

[0022] When conveying in the condition of having made conveyed objects, such as a particulate matter, full, relation (keeping) with the thrust of the screw 41 to the frictional force which acts between conveyed objects and screws 41 concerned becomes dominant.

[0023] First, keeping of the force in screw shaft orientations is considered. In the state of keeping, the sum of the component of a force of the direction of a revolving shaft is zero, and is expressed with following the (1) type.

[0024]

[Equation 3]

Here, if a coefficient of lateral pressure (the rate to the horizontal direction of the force of acting in the direction of a vertical is shown) is set to K, the relation of following the (2) type will be obtained.

[0025]

[Equation 4]

Following the (3) type is obtained from the perimeter of the wing section 42 in a screw 41, and the geometric relation to the screw itself.

[0026]

[Equation 5]

If the relation of (3) types is substituted for the above-mentioned (2) formula, following the (4) type will be obtained.

[0027]

[Equation 6]

If the above-mentioned (4) formula is replaced and arranged by following the (5) formula, following the (6) type will be obtained.

[0028]

[Equation 7]

Next, considering keeping of the force in the hand of cut of a screw, it is as follows.

[0029] That what is necessary is just to consider the component of a force of the perpendicular direction to a screw shaft as the moment, the sum is zero and following the (7) type is obtained. In addition, (7) types are **(ed) by R.

[0030]

[Equation 8]

Furthermore, (9) types will be obtained if it replaces with the notation which shows the multiplier of (7) types in following the (8) type.

[0031]

[Equation 9]

If the above-mentioned (9) formula is **(ed) by (6) formulas, and following the (10) type is placed with k and arranged, following the (11) type will be obtained.

[0032]

[Equation 10]

Here, following the (14) type is obtained by replacing the above-mentioned (11) formula with the notation shown in following the (12) type and (13) types.

[0033]

[Equation 11]

When it integrates with the above-mentioned (14) formula and initial condition is made into P=P0 by xb=0, the pressure Px in the location (x) of arbitration is expressed with following the (15) type.

[0034]

[Equation 12]

Moreover, the dimension relation of a screw shall be expressed like following the (16) type.

[0035]

[Equation 13]

By the way, when coefficient-of-friction mub of a conveyed object and tubed casing differs from coefficient-of-friction mus of a conveyed object and a screw and the direction of the slot in a screw wing is made into xb=L/sinalphab in order to change into screw shaft orientations, the pressure PL in distance L is expressed with following the (17) type from the inlet port in a general screw with a shaft.

[0036]

[Equation 14]

Furthermore, the pressure PL when the medial-axis object (henceforth a fixed axis) of immobilization shall be inserted in a screw into the main hole of a screw with a shaft to a general ribbon-like screw without a medial axis and this general ribbon-like screw is expressed with following the (18) type and (19) types, respectively. In this case, coefficient-of-friction mub of a conveyed object and tubed casing and coefficient-of-friction mus of a conveyed object and a screw consider as an equal (mu) mostly.

[0037] In the case of a ribbon-like screw;

[0038]

[Equation 15]

When a fixed axis is inserted in a ribbon-like screw;

[0039]

[Equation 16]

By the way, when it is in a fullness condition, for example, makes it lift and transport a conveyed object (particulate matter) to vertical above (for it not to be necessarily perpendicular), the pressure PL within tubed casing needs to take forward or the value of "zero" at least.

[0040] That is, in (17) types, while expressing briefly the formula of PL which

substituted phi= 90 degrees like following the (20) type, following the (21) type is obtained from the conditions from which the value of this (20) type serves as forward.

[0041]

PL=P0xS-Tx (S-1) ... (20)

In addition, S expresses the part of exp of the right-hand side of (17) types among (20) types, and T shows the anterior part of the 2nd term of the right-hand side of (17) types.

[0042] Here, if PL>=0, following the (21) type will be obtained.

P0>=Tx (1-1/S) ... (21)

Here, since it is **(1/S) 0, following the (22) type is obtained.

[0043] P0>=T ... (22)

In the above-mentioned (22) formula, the graph at the time of being referred to as P0=T, i.e., the need welding pressure in a screw conveyor, is shown in drawing 4 (conditions are shown all over drawing). In addition, more specifically (a) shows the case where it is the screw conveyor with vertical axes whose phi is 90 degrees. (b) shows the case where it is the perpendicular ribbon-like screw conveyor whose phi is similarly 90 degrees, and (c) shows the case where a fixed axis is inserted in the core of a perpendicular ribbon-like screw conveyor that similarly phi is 90 degrees. In addition, the axis of abscissa of drawing 4 shows a pressure, and the axis of ordinate shows the drained angle of repose theta (it mentions later).

[0044] Moreover, it can ask for the welding pressure (henceforth [it is also the pushing force and] generating welding pressure) in the screw conveyor 6 for pushing by (17) formulas by the same approach as the above. In this case, phi of (17) types is made into 0 times.

[0045] The generating welding pressure in the screw conveyor 6 for pushing is shown in drawing 4 (d) and (e), especially (d) shows the generating welding pressure by the screw conveyor with a horizontal axis, and (e) shows the generating welding pressure by the level ribbon-like screw conveyor.

[0046] Furthermore, drawing 4 (f) is a curve which shows the relation of the drained angle of repose theta and the discharge effectiveness eta in a screw conveyor. The above-mentioned discharge effectiveness eta is (the theoretical discharge of the real discharge / screw conveyor of a screw conveyor), and is expressed with following the (23) type.

[0047]

[Equation 17]

Eta=tantheta/(tan theta+tanalphab) ... (23)

Here, the discharge effectiveness eta and relation with the drained angle of repose theta

of a conveyed object are shown in drawing 5 .

[0048] In (b) of drawing 5 , when the particle of an A point moves to A' point by one rotation of a screw, it means that the particle had moved only one pitch t as theoretical, and the discharge effectiveness eta is set to 1.0. However, by friction with a screw and tubed casing, and a particle, supposing the particle of an A point moves to a B point, the migration length of a particle will be set to etat and the discharge effectiveness eta will become small from 1.0.

[0049] At this time, the eject direction of a particle became the line top which connects an A point and a B point, set the right-angled cross section and the angle to make to theta at the axial center of a screw, and has called this theta the drained angle of repose. Moreover, the development view of a screw wing is shown, the particle of an A point will move to a B point by one rotation of a screw, and, as for drawing 5 (a), the direction will have an include angle theta.

[0050] And if AC is made into the periphery die length (piDb) of screw wing 1 rotation, eta can be expressed with the above-mentioned (23) formula from the relation of piDb=etat (cotalphab+cottheta) and t=pi Dbtanalphab.

[0051] And (23) types which express this discharge effectiveness eta again can be expressed with the rotational frequency n of a screw as shown in following the (24) type.

[0052]

[Equation 18]

Eta=tantheta/(tan theta+tanalphab)

= Q/{(pi (Db2-Dr2)/4) (t-e) n} ... (24)

However, (24) types show the case of a screw with a shaft, and, in the case of a ribbon-like screw, (pi(Db2-Dr2)/4) in this formula of parts become with (piDb 2/4).

[0053] That is, from the above-mentioned (24) formula, if the discharge effectiveness eta and the theoretical discharge Q are known, it can ask for the rotational frequency n of a screw. However, what is necessary is just to determine with a rotational frequency n so that the discharge effectiveness eta may be satisfied in being a dimension about a screw, for example, having been decided mostly and changing Db, t, and e according to conveyance capacity etc.

[0054] Here, the efficient design approach of the screw conveyor for a transfer by lifting and the screw conveyor for pushing is explained using the graph shown in drawing 4 . In addition, a ribbon-like screw conveyor shall be used as a screw conveyor for pushing here, using a screw conveyor with a shaft as a screw conveyor for a transfer by lifting.

[0055] First, when designing a screw conveyor, the theoretical discharge Q based on a specification and its discharge effectiveness eta are determined as the beginning Q1 and

eta1 (setup). Then, the drained angle of repose theta 1 in case eta is the predetermined value eta 1 can be found from the curve of the discharge effectiveness eta shown in drawing 4 (f), and it turns out that welding-pressure deltaP needed with the screw conveyor with vertical axes corresponding to this theta 1 is deltaP1 from that curve (a).

[0056] That is, to a screw conveyor with vertical axes, it is conditions that it is larger than deltaP1, welding pressure required to push in the particulate matter which is a conveyed object, i.e., the generating welding pressure in the screw conveyor for pushing, therefore the discharge effectiveness eta 2 and the drained angle of repose theta 2 corresponding to deltaP1 can be found from the generating pressurization curve of the ribbon-like screw conveyor of drawing 4 (e).

[0057] Thus, based on the discharge effectiveness eta1 and eta2 in the screw conveyor for a transfer by lifting and the screw conveyor for press which were called for, screw speeds n1 and n2 are called for from the above-mentioned (23) formula.

[0058] And what is necessary is to select a rotation mechanical component, for example, a motor, and just to operate that it is also at these rotational frequencies n1 and n2, while determining the dimension of each part of a screw so that these rotational frequencies n1 and n2 can be obtained.

[0059] While making the screw 22 for a transfer by lifting in the screw-type transport device 1 of the material handling attachment 4 mentioned above as it is also at this rotational frequency n1 operate If the screw 32 for pushing is rotated as it is also at a rotational frequency n2, a particulate matter J can be certainly lifted and transported in the condition that could push that it was also at need welding pressure about the particulate matter J in boathouse 2a into the screw conveyor 5 side for a transfer by lifting, therefore it was full within the tubed casing 21. That is, like before, compared with the case where a particulate matter lifts and transports in the condition with a clearance within tubed casing, at least about (for example, it becomes 40 rotation extent from 500 rotation extent) 1/10 rotational frequency can be lifted and transported, therefore conveyance effectiveness is good, and wear of machines can also offer a screw-type transport device with little noise few.

[0060] Here, comparison examination is carried out about the welding pressure in each screw using a concrete numeric value. However, the dimension of the screw at the time of carrying out comparison examination is as follows.

Screw outer diameter : A Db=1.0 screw shaft diameter : (Bore diameter of a ribbon-like screw wing) In phii= 25-degree drawing 4 Dr=0.4Db screw pitch: -- t=1.0Db screw wing thickness: -- e=0.07Db screw blade height: -- H=0.3Db screw conveyor die-length: -- L=20Db coefficient-of-friction: -- s= mu b=mu 0.5 angle-of-internal-friction: -- (for

example, when setting discharge effectiveness to 0.33 for a perpendicular ribbon-like screw conveyor (i.e., when operating a drained angle of repose theta at 9 times), and when) The need welding pressure PR serves as about 1.3gammaDb, gamma is 1.2 t/m3, and when Db is 0.3m, the need welding pressure PR serves as 0.00459MPa(s) (2= 0.0468kg/cm2 of 1.3x1.2x0.3=0.468 t/m).

[0061] On the other hand, when discharge effectiveness operates a screw conveyor with vertical axes by 0.33 and operates a drained angle of repose theta at 9 times similarly When the need welding pressure PR serves as about 5gammaDb, gamma is 1.2 t/m3 and Db is 0.3m The need welding pressure PR will serve as 0.0176MPa(s) (2= 0.18kg/cm2 of 5x1.2x0.3=1.8 t/m), therefore need welding pressure will be 3.8 times the ribbon-like screw conveyor.

[0062] That is, compared with a ribbon-like screw conveyor, when discharge effectiveness eta is made the same, when there is no large welding pressure, in the case of a screw conveyor with vertical axes, it turns out that it cannot convey to a vertical.

[0063] Moreover, when a drained angle of repose theta exceeds 10 degrees from drawing 4 in the case of a screw conveyor with vertical axes, since the need welding pressure PR becomes large suddenly, the drained angle of repose theta in a screw conveyor with a shaft is considered that near 10 degrees is an economical upper limit, and its discharge effectiveness eta at this time is 0.36.

[0064] On the other hand, with the ribbon-like screw conveyor with which the fixed axis was inserted in the ribbon-like screw conveyor and the core, if a drained angle of repose theta exceeds 15 degrees, the need welding pressure PR will become large and a drained angle of repose theta will be considered that the neighborhood is an economical upper limit 20 degrees. The discharge effectiveness eta at this time is 0.54.

[0065] In such a screw conveyor for a transfer by lifting, it is desirable that the discharge effectiveness eta operates in 0.1-0.6 (a drained angle of repose theta the range of two - 25 degrees) (except for the example of a screw conveyor with vertical axes).

[0066] Next, the screw conveyor for pushing is explained using a concrete numeric value. In the screw conveyor for pushing, operation to which the welding pressure PL becomes larger than the need welding pressure PR of the screw conveyor for a transfer by lifting is performed.

[0067] In drawing 4 , with the same welding pressure as the need welding pressure in nine drained angles of repose of a perpendicular ribbon-like screw conveyor If the ribbon-like screw conveyor with which the fixed axis was inserted in the core is operated As opposed to the discharge effectiveness eta of a perpendicular ribbon-like screw conveyor being 0.33 The discharge effectiveness in the ribbon-like screw conveyor with

which the fixed axis was inserted in the core which generates the need welding pressure at this time is set to 0.42, and it turns out that the direction of the ribbon-like screw conveyor with which the fixed axis was inserted in the core has good discharge effectiveness.

[0068] To a drained angle of repose theta being [the discharge effectiveness eta] 0.38 at 11 degrees, in the case of a level ribbon-like screw conveyor, 25 degrees, a drained angle of repose is 0.6 and will be [discharge effectiveness] moreover, satisfied with the screw conveyor with a horizontal axis which generates the need welding pressure when operating a screw conveyor with vertical axes by the drained angle of repose theta of 9 times of the need welding pressure of a screw conveyor with vertical axes. This means that the miniaturization of a level ribbon-like screw conveyor can be attained. On the contrary, discharge effectiveness can also operate [a drained angle of repose] a perpendicular ribbon-like screw conveyor by about 0.6 about 23 degrees. Moreover, when operating the ribbon-like screw conveyor with which the fixed axis was inserted in the core by nine drained angles of repose, the discharge effectiveness eta is set to 0.8 at 40 degrees, and a drained angle of repose theta can carry out still more efficient operation in the ribbon-like screw conveyor with which the fixed axis was inserted in the core.

[0069] By the way, in the gestalt of the above-mentioned implementation, you may be the ribbon-like screw by which the fixed axis has been arranged in the ribbon-like screw or the core although the screw with a shaft was explained as a screw 22 for a transfer by lifting, and although the ribbon-like screw was further explained as a screw 32 for pushing, you may be a screw with a shaft.

[0070] Furthermore, although one screw conveyor 6 for horizontal pushing for it being horizontal to the screw conveyor 5 for a transfer by lifting mostly arranged in the direction of a vertical, and stuffing a conveyed object into it was formed in the screw-type transport device concerning the gestalt of the above-mentioned implementation as shown in drawing 2 For example, you may make it prepare screw conveyor 6B for inclination pushing pushed in by slanting above one between screw conveyor 6A for pushing which it is horizontal and is pushed in, and the screw conveyor 5 for a transfer by lifting, as shown in drawing 6 .

[0071] That is, when the specific gravity gamma of a conveyed object becomes large at each coefficient-of-friction mu list between a conveyed object, tubed casing, and a screw, the supercharge pressure P0 for making it the pressure within the screw conveyor 5 for a transfer by lifting become more than zero (PL>=0) becomes excessive, but as mentioned above, such an excessive supercharge pressure can be coped with by

arranging the screw conveyor for pushing to two steps.

[0072] In screw conveyor 6B for inclination pushing, screw conveyor 6A for horizontal pushing receives screw conveyor 6B for inclination pushing through the movable joint 51 to the screw conveyor 5 for a transfer by lifting. Moreover, with the movable joint 52 While being connected respectively free [rocking], among each screw conveyor 5:6B and 6B:6A, the mutual cylinder equipments 53 and 54 for posture adjustment are formed, and it is constituted so that any shipping postures (shipment condition) of a conveyed object can be coped with.

[0073]

[Effect of the Invention] From the need pressurization curve in the screw which is obtained from the formula showing the pressure in tubed casing in the condition that the conveyed object was full, as mentioned above according to the design approach of the screw-type transport device of this invention While asking for the need welding pressure in the screw conveyor for a transfer by lifting corresponding to predetermined discharge effectiveness A transfer by lifting can be ensured [efficiently and] by asking for the engine speed of a screw from a discharge efficiency curve in the condition of having made the conveyed object full by making the screw conveyor for press driving the thrust exceeding this need welding pressure being also. That is, like before, compared with the case where a conveyed object is lifted and transported in the condition with a clearance within tubed casing, it can lift and transport that low-speed rotation is also, therefore conveyance effectiveness is good, and wear of machines can also offer a screw-type transport device with little noise few.

[Brief Description of the Drawings]

[Drawing 1] It is the side elevation showing the busy condition of the screw-type transport device in the gestalt of operation of this invention.

[Drawing 2] It is the sectional view of this screw-type transport device.

[Drawing 3] It is the important section enlarged drawing of the screw explaining the principle for asking for the pressure within tubed casing of this screw-type transport device.

[Drawing 4] It is the graph which shows a discharge efficiency curve to the need pressurization curve within each tubed casing of this screw-type transport device, and a generating pressurization curvilinear list.

[Drawing 5] It is drawing explaining the relation of the discharge effectiveness and the drained angle of repose in this screw-type transport device.

[Drawing 6] It is the side elevation showing the busy condition in the modification of this screw-type transport device.

[Description of Notations]

1 Screw-type Transport Device

5 Screw Conveyor for Transfer by Lifting

6 Screw Conveyor for Pushing

21 Tubed Casing

21a Feed hopper

22 Screw for Transfer by Lifting

26 Motor

31 Tubed Casing

32 Screw for Pushing

33 Motor

(19)日本国特許庁（ＪＰ）

(12) 公開特許公報 (A)

(11)特許出願公開番号
特開2003－54730
(P2003－54730A)

(43)公開日　平成15年2月26日(2003.2.26)

(51)Int.Cl.^{7}	識別記号	ＦＩ	テーマコード(参考)
Ｂ６５Ｇ　33/14		Ｂ６５Ｇ　33/14	３Ｆ０４０
33/26		33/26	

審査請求　未請求　請求項の数１　ＯＬ　(全 11 頁)

(21)出願番号　特願2001－241474(P2001－241474)

(22)出願日　平成13年8月9日(2001.8.9)

(71)出願人　000005119
日立造船株式会社
大阪府大阪市住之江区南港北１丁目７番89号

(72)発明者　吉川　忠男
大阪府大阪市住之江区南港北１丁目７番89号　日立造船株式会社内

(74)代理人　100068087
弁理士　森本　義弘

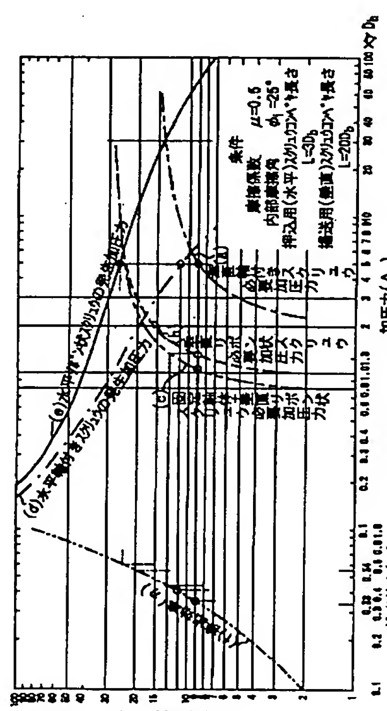
Ｆターム(参考)　3F040 BA01 CA08 EA01 EA02 EA03 EA04

(54)【発明の名称】　スクリュウ式搬送装置の設計方法

(57)【要約】

【課題】搬送効率の良いスクリュウ式搬送装置の設計方法を提供する。

【解決手段】被搬送物の揚送用スクリュウコンベヤと、この揚送用コンベヤに被搬送物を押し込む押込用スクリュウコンベヤとを有する搬送装置の設計方法であって、筒状ケーシング内に充満された被搬送物の任意位置での圧力を示す式から、揚送用筒状ケーシング内での必要加圧力を示す必要加圧曲線、押込用筒状ケーシングでの発生加圧力を示す発生加圧曲線を求め、そして排出効率曲線を用いて設計排出効率に対応する排出角を求め、この排出角に応じた必要加圧曲線から揚送に必要な加圧力を求め、この加圧力以上の発生加圧力を、押込用コンベヤにて発生させるようになし、且つこの発生加圧力に応じた押込用コンベヤでの排出効率及び設計排出効率並びに設計搬送量に基づき、揚送用及び押込用コンベヤにおける各スクリュウの回転数を求める方法である。



【特許請求の範囲】

【請求項１】揚送用スクリュウが傾斜された筒状ケーシング内に回転自在に配置されてなる揚送用スクリュウコンベヤと、押込用スクリュウがほぼ水平に配置された筒状ケーシング内に回転自在に配置されてなる押込用スクリュウコンベヤとを有し、且つこの押込用スクリュウコンベヤにより、上記揚送用スクリュウコンベヤ内に、被搬送物を押し込み上記傾斜筒状ケーシング内にて被搬送物が充満した状態で揚送を行うようにしたスクリュウ式搬送装置の設計方法であって、

筒状ケーシング内のスクリュウの回転軸心方向での力の釣合およびスクリュウの回転円周方向での力の釣合から得られる筒状ケーシング内で充満された被搬送物の任意位置での圧力（P_L）を示す下記式を、筒状ケーシング内で被搬送物が充満されて$P_L \geqq 0$であるという条件を用いて変形することにより、

排出角θと傾斜筒状ケーシング内での必要加圧力との関係を示す必要加圧曲線、および排出角θと水平筒状ケーシングでの発生加圧力との関係を示す発生加圧曲線を求めるとともに、上記排出角θと排出効率ηとの関係を示す排出効率曲線を求め、

上記排出効率曲線に基づき、所定の排出効率に対応する排出角を求めるとともに、この排出角に応じて上記必要加圧曲線から揚送に必要な加圧力を求め、

この加圧力以上の発生加圧力を、上記押込用スクリュウコンベヤにて発生させるようにするとともに、この発生加圧力に応じて、上記発生加圧曲線および排出効率曲線から、当該押込用スクリュウコンベヤにおける排出効率を求め、

さらに上記揚送用スクリュウコンベヤおよび押込用スクリュウコンベヤにおける各スクリュウの回転数を、各排出効率と設計搬送量との関係から求めることを特徴とするスクリュウ式搬送装置の設計方法。

【数１】

$$P_L = P_o \exp\left[\frac{KL\{\mu_b(\cos\alpha_b\cos\theta - k\cos\alpha_b\sin\theta) - \mu_s[2HE/(t-e)](k\sin\alpha_m + E\cos\alpha_m) - \mu_s C(k\sin\alpha_r\cos\alpha_r + C\cos^2\alpha_r)\}}{H\sin\alpha_b\cos\alpha_m(k\sin\alpha_m + E\cos\alpha_m)}\right]$$

$$-\frac{HE\gamma\cos\alpha_m(k\sin\phi - \mu_b\cos\phi)}{K\{\mu_b(\cos\alpha_b\cos\theta - k\cos\alpha_b\sin\theta) - \mu_s[2HE/(t-e)](k\sin\alpha_m + E\cos\alpha_m) - \mu_s C(k\sin\alpha_r\cos\alpha_r + C\cos^2\alpha_r)\}}$$

$$\times\left[\exp\left(\frac{KL\{\mu_b(\cos\alpha_b\cos\theta - k\cos\alpha_b\sin\theta) - \mu_s[2HE/(t-e)](k\sin\alpha_m + E\cos\alpha_m) - \mu_s C(k\sin\alpha_r\cos\alpha_r + C\cos^2\alpha_r)\}}{H\sin\alpha_b\cos\alpha_m(k\sin\alpha_m + E\cos\alpha_m)}\right) - 1\right]$$

但し、上記式中における記号の意味は、下記の通りである。

C：定数＝（D_b－２Ｈ）／D_b

D_b：スクリュウ外径

Ｅ：定数＝（D_b－Ｈ）／D_b

Ｈ：スクリュウ溝深さ

Ｋ：側圧係数＝（$1-\sin^2\phi_i/1+\sin^2\phi_i$）

Ｌ：スクリュウコンベヤ有効長さ

P_L：コンベヤ長さＬにおける圧力

P_0：コンベヤ入口における圧力

ｅ：スクリュウ羽根厚

ｔ：スクリュウピッチ

α_b：スクリュウ外径のねじれ角

α_m：スクリュウ平均径のねじれ角

α_r：スクリュウ軸径のねじれ角

θ：排出角

ϕ：スクリュウコンベヤの傾斜角

μ_b：被搬送物と筒状ケーシング内面との摩擦係数

μ_s：被搬送物とスクリュウ羽根面との摩擦係数

をそれぞれ表す。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、スクリュウ式搬送装置の設計方法に関する。

【０００２】

【従来の技術】大深度のトンネル掘削工事から排出される土砂、船倉内の鉱石、粉粒体（穀物を含む）等を揚出する場合、例えばスクリュウコンベヤが用いられるとともに、ほぼ鉛直方向で搬送（揚送）が行われている。

【０００３】そして、このような急傾斜での搬送を行うスクリュウコンベヤの場合、被搬送物は、スクリュウ羽根の回転に基づく遠心力により、ケーシング内面に押し付けられた状態で、搬送が行われていた。

【０００４】

【発明が解決しようとする課題】上述したスクリュウコンベヤによると、被搬送物は遠心力によりケーシング内面に押し付けられた状態でほぼ鉛直面を上昇されることになり、したがってケーシング内での充満率が低下して搬送効率が悪くなり、またコンベヤ自体の摩耗が早く進むとともに、スクリュウ自体が例えば５００ＲＰＭのような高速で回転されるため、運転時の騒音が大きいなどの問題があった。

【０００５】そこで、本発明は、搬送効率の良いスクリュウ式搬送装置の設計方法を提供することを目的とす

る。
【０００６】
【課題を解決するための手段】上記課題を解決するために、本発明のスクリュウ式搬送装置の設計方法は、揚送用スクリュウが傾斜された筒状ケーシング内に回転自在に配置されてなる揚送用スクリュウコンベヤと、押込用スクリュウがほぼ水平に配置された筒状ケーシング内に回転自在に配置されてなる押込用スクリュウコンベヤとを有し、且つこの押込用スクリュウコンベヤにより、上記揚送用スクリュウコンベヤ内に、被搬送物を押し込み上記傾斜筒状ケーシング内にて被搬送物が充満した状態で揚送を行うようにしたスクリュウ式搬送装置の設計方法であって、筒状ケーシング内のスクリュウの回転軸心方向での力の釣合およびスクリュウの回転円周方向での力の釣合から得られる筒状ケーシング内で充満された被搬送物の任意位置での圧力（P_L）を示す下記式を、筒状ケーシング内で被搬送物が充満されて$P_L \geqq 0$であるという条件を用いて変形することにより、排出角θと傾斜筒状ケーシング内での必要加圧力との関係を示す必要加圧曲線、および排出角θと水平筒状ケーシングでの発生加圧力との関係を示す発生加圧曲線を求めるとともに、上記排出角θと排出効率ηとの関係を示す排出効率曲線を求め、上記排出効率曲線に基づき、所定の排出効率に対応する排出角を求めるとともに、この排出角に応じて上記必要加圧曲線から揚送に必要な加圧力を求め、この加圧力以上の発生加圧力を、上記押込用スクリュウコンベヤにて発生させるようにするとともに、この発生加圧力に応じて、上記発生加圧曲線および排出効率曲線から、当該押込用スクリュウコンベヤにおける排出効率を求め、さらに上記揚送用スクリュウコンベヤおよび押込用スクリュウコンベヤにおける各スクリュウの回転数を、各排出効率と設計搬送量との関係から求める方法である。
【０００７】
【数２】

$$P_L = P_o \exp\left[\frac{KL\{\mu_b(\cos\alpha_b\cos\theta - k\cos\alpha_b\sin\theta) - \mu_s[2HE/(t-e)](k\sin\alpha_m + E\cos\alpha_m) - \mu_s C(k\sin\alpha_r\cos\alpha_r + C\cos^2\alpha_r)\}}{H\sin\alpha_b\cos\alpha_m(k\sin\alpha_m + E\cos\alpha_m)}\right]$$

$$-\frac{HE\gamma\cos\alpha_m(k\sin\phi - \mu_b\cos\phi)}{K\{\mu_b(\cos\alpha_b\cos\theta - k\cos\alpha_b\sin\theta) - \mu_s[2HE/(t-e)](k\sin\alpha_m + E\cos\alpha_m) - \mu_s C(k\sin\alpha_r\cos\alpha_r + C\cos^2\alpha_r)\}}$$

$$\times\left[\exp\left(\frac{KL\{\mu_b(\cos\alpha_b\cos\theta - k\cos\alpha_b\sin\theta) - \mu_s[2HE/(t-e)](k\sin\alpha_m + E\cos\alpha_m) - \mu_s C(k\sin\alpha_r\cos\alpha_r + C\cos^2\alpha_r)\}}{H\sin\alpha_b\cos\alpha_m(k\sin\alpha_m + E\cos\alpha_m)}\right) - 1\right]$$

但し、上記式中における記号の意味は、下記の通りである。
C：定数＝（D_b－２Ｈ）／D_b
D_b：スクリュウ外径
Ｅ：定数＝（D_b－Ｈ）／D_b
Ｈ：スクリュウ溝深さ
Ｋ：側圧係数＝（１－ｓｉｎ$^2\phi_i$／１＋ｓｉｎ$^2\phi_i$）
Ｌ：スクリュウコンベヤ有効長さ
P_L：コンベヤ長さＬにおける圧力
P_0：コンベヤ入口における圧力
ｅ：スクリュウ羽根厚
ｔ：スクリュウピッチ
α_b：スクリュウ外径のねじれ角
α_m：スクリュウ平均径のねじれ角
α_r：スクリュウ軸径のねじれ角
θ：排出角
ϕ：スクリュウコンベヤの傾斜角
μ_b：被搬送物と筒状ケーシング内面との摩擦係数
μ_s：被搬送物とスクリュウ羽根面との摩擦係数
をそれぞれ表す。
【０００８】上記の設計方法によると、被搬送物が充満された状態の筒状ケーシング内の圧力を表す計算式から得られるスクリュウでの必要加圧曲線から、所定の排出効率に対応する揚送用スクリュウコンベヤにおける必要加圧力を求めるとともに、排出効率曲線からスクリュウの回転数を求め、そしてこの必要加圧力を越える押圧力でもって押圧用スクリュウコンベヤを駆動させることにより、被搬送物を充満させた状態で揚送を効率良く且つ確実に行うことができる。すなわち、筒状ケーシング内で隙間を有した状態で被搬送物を揚送する場合に比べて、低速回転でもって揚送することができ、したがって搬送効率が良く、機械同士の摩耗も少なく、且つ騒音が少ないスクリュウ式搬送装置を得ることができる。
【０００９】
【発明の実施の形態】以下、本発明の実施の形態におけるスクリュウ式搬送装置の設計方法を、図１～図５に基づき説明する。
【００１０】まず、本発明に係るスクリュウ式搬送装置の概略構成を、図１および図２に基づき説明する。このスクリュウ式搬送装置１は、例えば貨物船２の船倉２ａ内に積載された粉粒体（被搬送物の一例）Ｊを岸壁（陸上）Ｇに設けられた貯留用ホッパー３に荷揚げするための荷役装置４に設けられており、ほぼ鉛直方向で配置されて粉粒体Ｊを下方から上方に搬送（以下、揚送という）する揚送用スクリュウコンベヤ５と、ほぼ水平方向に配置されて上記揚送用スクリュウコンベヤ５の下部内

に粉粒体を押し込むための押込用スクリュウコンベヤ６とから構成されている。

【００１１】なお、荷役装置４には、岸壁Ｇに接岸された貨物船２に沿って設けられたガイドレール上を走行自在にされた門型の走行フレーム１１と、この走行フレーム１１の上方に設けられるとともに岸壁上から接岸された貨物船２上に延設されたガーダ部材１２と、このガーダ部材１２の先端部から垂下された支持部材（図示せず）に支持された揚送用スクリュウコンベヤ５と、上記支持部材の下端部に設けられて船倉２ａ内の粉粒体Ｊを複数個のバケット１３ａにより採集する採集機１３と、この採集機１３により採集された粉粒体Ｊを上記揚送用スクリュウコンベヤ５に押し込むための押込用スクリュウコンベヤ６と、上記ガーダ部材１２に配置されて揚送用スクリュウコンベヤ５により上方まで搬送された粉粒体Ｊを岸壁Ｇ上まで水平方向に搬送するベルトコンベヤ１４と、このベルトコンベヤ１４にて搬送された粉粒体Ｊを貯留用ホッパー３に案内するためのジュート１５とから構成されている。

【００１２】次に、粉粒体Ｊを搬送するためのスクリュウ式搬送装置１を、図２に基づき説明する。なお、このスクリュウ式搬送装置１は、揚送用スクリュウコンベヤ５および押込用スクリュウコンベヤ６から構成されているが、まず、揚送用スクリュウコンベヤ５について説明する。

【００１３】すなわち、この揚送用スクリュウコンベヤ５は、支持部材に鉛直方向で支持された筒状ケーシング２１と、この筒状ケーシング２１内に回転自在に配置されるとともに軸部（以下、スクリュウ軸ともいう）２２ａの外周に羽根部（以下、スクリュウ羽根ともいう）２２ｂが設けられてなる揚送用スクリュウ（軸付きスクリュウである）２２と、この揚送用スクリュウ２２を回転させる回転駆動装置２３とから構成されている。なお、図２から分かるように、長いスクリュウをそれ程振れることなく回転させるために３箇所で回転させるようにしている。勿論、これら各回転箇所における筒状ケーシング２１には、揚送用スクリュウ２２の外周に固着された回転環（図示せず）がそれぞれ回転自在に設けられるとともに、これらの回転環が、伝導軸２４および歯車機構２５を介して、一台の電動機２６により回転駆動される。勿論、伝導軸および歯車機構を介さずに、途中に複数台の電動機を配置して、それぞれにより揚送用スクリュウを回転させることもできる。

【００１４】次に、押込用スクリュウコンベヤ６は、ほぼ水平方向で配置されるとともに、前端部が揚送用スクリュウコンベヤ５の筒状ケーシング２１の下端供給口２１ａに接続され且つ後端部に粉粒体の供給口３１ａが形成された筒状ケーシング３１と、この筒状ケーシング３１内に回転自在に配置されるとともに軸部を有しないリボン状に形成された押込用スクリュウ３２と、この押込用スクリュウ３２を、その外周に設けられた回転環（図示せず）を歯車機構を介して回転させる電動機３３とから構成されている。

【００１５】ここで、上記各スクリュウ２２，３２を回転さる回転環の構成を簡単に説明しておく。この回転環を用いた構成は、スクリュウ羽根の外周に、所定幅で且つ円環状に形成された回転環を固着させるとともに、この回転環を、筒状ケーシング側に回転自在に支持し、そしてこの回転環を、その外周面に設けられたリングギヤを介して電動機により回転させるようにしたものである。

【００１６】ところで、上述したように、本発明の要旨は、揚送用スクリュウコンベヤ５の筒状ケーシング２１の下部内に供給された被搬送物に圧力を加えて、筒状ケーシング２１内全体に亘って充満させることにより、効率良く且つ低速ですなわち騒音の小さい搬送を行い得るような装置、特にその設計方法を提供することにある。

【００１７】このようなスクリュウコンベヤを設計するに際し、重要なことは、筒状ケーシング内での被搬送物の加圧状態すなわち圧力状態（搬送圧ともいう）を知ることであり、そこで、本発明者は被搬送物の圧力状態を理論的に解明し、筒状ケーシング内における任意位置での圧力を表す計算式を導き出すとともに、この計算式に基づき、スクリュウコンベヤの諸元（仕様）を求めるようにしたものである。

【００１８】以下、スクリュウが回転自在に配置された筒状ケーシング内で充満された被搬送物の圧力を求める計算式の導き方について説明する。ここでは、適用対象をできるだけ一般化するために、搬送方向が水平から鉛直までのものに適用し得る様に、またスクリュウ形式を一般化するために、軸付きスクリュウコンベヤとして説明し、さらに被搬送物としては、粉粒体、塊状物などのように、スクリュウコンベヤとの間に摩擦力が作用するものに適用する。

【００１９】なお、式を簡単にするため、次の仮定を設けている。

①筒状ケーシング内の被搬送物（粉粒体）は、全ての面に接触している。

②圧力は、スクリュウ羽根における溝部の長さ（ｘ）の関数である。

【００２０】③被搬送物とスクリュウコンベヤ側の接触面との摩擦係数は、圧力とは無関係に、全長に亘って一定である。

④スクリュウの外径と筒状ケーシングとの隙間は無視する。

【００２１】⑤スクリュウ羽根における溝部内の被搬送物はプラグとして動く。

ここで、以下に示す式中に用いられる記号について説明する。

［記号の説明］

C：定数＝（D_b－２H）／D_b
D_b：スクリュウ外径
D_m：スクリュウ平均径
D_r：スクリュウ軸径（リボン状スクリュウ羽根の穴径）
E：定数＝（D_b－H）／D_b
H：スクリュウ溝深さ
K：側圧係数＝（１－ｓｉｎ$^2\phi_i$／１＋ｓｉｎ$^2\phi_i$）
L：スクリュウコンベヤ有効長さ
P_L：コンベヤ長さLにおける圧力
P_0：コンベヤ入口における圧力
R：スクリュウ半径
W：スクリュウ羽根の有効幅
e：スクリュウ羽根厚
t：スクリュウピッチ
α_b：スクリュウ外径のねじれ角
α_m：スクリュウ平均径のねじれ角
α_r：スクリュウ軸径のねじれ角
γ：被搬送物の嵩密度
η：排出効率
θ：排出角
ϕ_i：被搬送物の内部摩擦角
ϕ：スクリュウコンベヤの傾斜角
μ_b：被搬送物と筒状ケーシング内面との摩擦係数（ρ_b＝ｔａｎ$^{-1}\mu_b$）
μ_s：被搬送物とスクリュウ羽根面との摩擦係数（ρ_s＝ｔａｎ$^{-1}\mu_s$）
添　字
ｂ：スクリュウ外径部
ｆｐ：スクリュウ側面押し側
ｆｆ：スクリュウ側面引き側
ｍ：スクリュウ平均（中央）径部
ｒ：スクリュウ根元径部

図３は、スクリュウ４１における羽根部４２の１ピッチ分、すなわちスクリュウ羽根の溝部４３に充満された被搬送物の微小部分に作用する静的な力の平衡状態を示している。

【００２２】粉粒体などの被搬送物を充満させた状態で搬送する場合は、当該被搬送物とスクリュウ４１との間に作用する摩擦力に対するスクリュウ４１の推力との関係（釣合）が支配的となる。

【００２３】まず、スクリュウ軸方向での力の釣合を考える。釣合状態では、回転軸方向の分力の和はゼロであり、下記（１）式にて表される。

【００２４】

【数３】

$$dF_n \cos\alpha_m - dF_n\mu_s \sin\alpha_m = dF_b\mu_b \sin\theta + 2dF_f\mu_s \sin\alpha_m + dF_r\mu_s \sin\alpha_r + W_m HdP \sin\alpha_m + W_m Hdx_m\gamma \sin\phi \quad \cdots(1)$$

ここで、側圧係数（鉛直方向に作用する力の水平方向への割合を示す）をKとすると、下記（２）式の関係が得られる。

【００２５】

【数４】

$$\left.\begin{aligned} dF_b &= W_b KPdx_b \\ dF_f &= HKPdx_m \\ dF_r &= W_r KPdx_r \end{aligned}\right\}\cdots(2)$$

スクリュウ４１における羽根部４２の周長とスクリュウ自体における幾何学的関係とから、下記（３）式が得られる。

【００２６】

【数５】

$$\left.\begin{aligned} dx_m / dx_b &= (D_b - H) / D_b = E \\ dx_r / dx_b &= (D_b - 2H) / D_b = C \end{aligned}\right\}\cdots(3)$$

上記（２）式に（３）式の関係を代入すると、下記（４）式が得られる。

【００２７】

【数６】

$$dF_n(\cos\alpha_m - \mu_s \sin\alpha_m) = dx_b[W_b KP\mu_b \sin\theta + 2HEKP\mu_s \sin\alpha_m + W_r KP\mu_s C \sin\alpha_r + W_m HdP / dx_b \cdot \sin\alpha_m + W_m HE\gamma \sin\phi] \quad \cdots(4)$$

上記（４）式を、下記（５）式にて置き換え整理すると、下記（６）式が得られる。

【００２８】

【数７】

$$\left.\begin{aligned} A_1 &= dx_b\{W_b\mu_b \sin\theta + 2HE\mu_s \sin\alpha_m + W_r C\mu_s \sin\alpha_r\} \\ A_2 &= dx_b W_m H \sin\alpha_m \\ A_3 &= dx_b W_m HE\gamma \sin\phi \end{aligned}\right\}\cdots(5)$$

$$dF_n(\cos\alpha_m - \mu_s \sin\alpha_m) = (A_1 KP + A_2 dP / dx_b + A_3)dx_b \quad \cdots(6)$$

次に、スクリュウの回転方向での力の釣合を考えると以下のようになる。

【００２９】スクリュウ軸に対する垂直方向の分力はモーメントとして考えればよく、その和はゼロで、下記（７）式が得られる。なお、（７）式は、Rで除されている。

【００３０】

【数８】

$$
\begin{aligned}
&dF_n(E\sin\alpha_m + E\mu_s\cos\alpha_m) = W_bKPdx_b\mu_b\cos\theta - 2HKPEdx_m\mu_s\cos\alpha_m \\
&- W_rKPC\mu_s\cos\alpha_r - W_mHEdP\cos\alpha_m + W_mHdx_m\gamma\mu_b\cos\phi \\
&= dx_b\Big[W_bKP\mu_b\cos\theta - 2HE^2KP\mu_s\cos\alpha_m - W_rKP\mu_sC^2\cos\alpha_r \\
&\qquad - W_mHEd\,P/dx_b \cdot \cos\alpha_m + W_mHE\gamma\mu_b\cos\phi\Big] \qquad \cdots(7)
\end{aligned}
$$

さらに、（７）式の係数を、下記（８）式に示す記号で置き換えると、（９）式が得られる。

【００３１】

【数９】

$$
\left.\begin{aligned}
B_1 &= dx_b\left\{W_b\mu_b\cos\theta - 2HE^2\mu_s\cos\alpha_m - C^2\mu_s\cos\alpha_r\right\} \\
B_2 &= dx_bW_mHE\cos\alpha_m \\
B_3 &= dx_bW_mHE\gamma\mu_b\cos\phi
\end{aligned}\right\} \qquad \cdots(8)
$$

$$
dF_n(E\sin\alpha_m + E\mu_s\cos\alpha_m) = (B_1KP - B_2d\,P/d\,x_b + B_3)dx_b \qquad \cdots(9)
$$

上記（９）式を（６）式で除して下記（１０）式をｋと置いて整理すると、下記（１１）式が得られる。

【００３２】

【数１０】

$$
k = \frac{E(\sin\alpha_m + \mu_s\cos\alpha_m)}{\cos\alpha_m - \mu_s\sin\alpha_m} = E\tan(\alpha_m + \rho_s) = \frac{B_1KPdx_b - B_2dP + B_3dx_b}{A_1KPdx_b + A_2dP + A_3dx_b} \cdots(10)
$$

$$
\frac{dP}{dx_b} + \frac{K(kA_1 - B_1)}{(kA_2 + B_2)}P = -\frac{(kA_3 - B_3)}{(kA_2 + B_2)} \qquad \cdots(11)
$$

ここで、上記（１１）式を、下記（１２）式および（１３）式に示す記号で置き換えることにより、下記（１４）式が得られる。

【００３３】

【数１１】

$$
M = \frac{K(kA_1 - B_1)}{(kA_2 + B_2)} \qquad \cdots(12)
$$

$$
N = \frac{(kA_3 - B_3)}{(kA_2 + B_2)} \qquad \cdots(13)
$$

$$
\frac{dP}{dx_b} + MP = -N \qquad \cdots(14)
$$

上記（１４）式を積分して、初期条件をx_b＝０で、Ｐ＝P_0とすると、任意の位置（ｘ）における圧力P_xは下記（１５）式にて表される。

【００３４】

【数１２】

$$
P_x = P_o\,exp(-Mx_b) + \frac{N}{M}\left[exp(-Mx_b) - 1\right] \qquad \cdots(15)
$$

また、スクリュウの寸法関係を下記（１６）式のように表すものとする。

【００３５】

【数１３】

$$
\left.\begin{aligned}
W_b &= (t - e)\cos\alpha_b \\
W_m &= (t - e)\cos\alpha_m \\
W_r &= (t - e)\cos\alpha_r
\end{aligned}\right\} \qquad \cdots(16)
$$

ところで、被搬送物と筒状ケーシングとの摩擦係数μ_bと、被搬送物とスクリュウとの摩擦係数μ_sとが異なるとき、スクリュウ羽根における溝部の方向を、スクリュウ軸方向に変換するために、x_b＝Ｌ／ｓｉｎα_bとすると、一般的な軸付きスクリュウにおける入口から距離Ｌにおける圧力P_Lは、下記（１７）式で表される。

【００３６】

【数１４】

$$
\begin{aligned}
P_L = P_o \exp&\left[\frac{KL\{\mu_b(\cos\alpha_b\cos\theta - k\cos\alpha_b\sin\theta) - \mu_s[2HE/(t-e)](k\sin\alpha_m + E\cos\alpha_m) - \mu_sC(k\sin\alpha_r\cos\alpha_r + C\cos^2\alpha_r)\}}{H\sin\alpha_b\cos\alpha_m(k\sin\alpha_m + E\cos\alpha_m)}\right] \\
&- \frac{HE\gamma\cos\alpha_m(k\sin\phi - \mu_b\cos\phi)}{K\{\mu_b(\cos\alpha_b\cos\theta - k\cos\alpha_b\sin\theta) - \mu_s[2HE/(t-e)](k\sin\alpha_m + E\cos\alpha_m) - \mu_sC(k\sin\alpha_r\cos\alpha_r + C\cos^2\alpha_r)\}} \\
&\times\left[\exp\left(\frac{KL\{\mu_b(\cos\alpha_b\cos\theta - k\cos\alpha_b\sin\theta) - \mu_s[2HE/(t-e)](k\sin\alpha_m + E\cos\alpha_m) - \mu_sC(k\sin\alpha_r\cos\alpha_r + C\cos^2\alpha_r)\}}{H\sin\alpha_b\cos\alpha_m(k\sin\alpha_m + E\cos\alpha_m)}\right) - 1\right] \\
&\cdots(17)
\end{aligned}
$$

さらに、スクリュウを一般の軸付きスクリュウから、中心軸が無いリボン状スクリュウおよびこのリボン状スクリュウの中心穴部内に固定の中心軸体（以下、固定軸体という）が挿入されたものとした場合の圧力P_Lは、それぞれ下記（１８）式および（１９）式にて表される。この場合、被搬送物と筒状ケーシングとの摩擦係数μ_bと、被搬送物とスクリュウとの摩擦係数μ_sとがほぼ等しいもの（μ）とする。

【００３７】リボン状スクリュウの場合；　【数１５】
【００３８】

$$P_L = P_o \exp\left[\frac{\mu KL\{\cos\alpha_b\cos\theta - k\cos\alpha_b\sin\theta - [2HE/(t-e)](k\sin\alpha_m + E\cos\alpha_m)\}}{H\sin\alpha_b\cos\alpha_m(k\sin\alpha_m + E\cos\alpha_m)}\right]$$
$$-\left[\frac{HE\gamma\cos\alpha_m(k\sin\phi - \mu\cos\phi)}{\mu K\{\cos\alpha_b\cos\theta - k\cos\alpha_b\sin\theta - [2HE/(t-e)](k\sin\alpha_m + E\cos\alpha_m)\}}\right]$$
$$\times\left[\exp\left(\frac{\mu KL\{\cos\alpha_b\cos\theta - k\cos\alpha_b\sin\theta - [2HE/(t-e)](k\sin\alpha_m + E\cos\alpha_m)\}}{H\sin\alpha_b\cos\alpha_m(k\sin\alpha_m + E\cos\alpha_m)}\right) - 1\right] \quad \cdots(18)$$

リボン状スクリュウに固定軸体が挿入された場合；　【数１６】
【００３９】

$$P_L = P_O \exp\left[\frac{\mu KL\{(\cos\alpha_b + C^2\cos\alpha_r)\cos\theta - k(\cos\alpha_b + C\cos\alpha_r)\sin\theta - [2HE/(t-e)](k\sin\alpha_m + E\cos\alpha_m)\}}{H\sin\alpha_b\cos\alpha_m(k\sin\alpha_m + E\cos\alpha_m)}\right]$$
$$-\frac{HE\gamma\cos\alpha_m(k\sin\phi - \mu_b\cos\phi)}{\mu K\{(\cos\alpha_b + C^2\cos\alpha_r)\cos\theta - k(\cos\alpha_b + C\cos\alpha_r)\sin\theta - [2HE/(t-e)](k\sin\alpha_m + E\cos\alpha_m)\}}$$
$$\times\left[\exp\left(\frac{\mu KL\{(\cos\alpha_b + C^2\cos\alpha_r)\cos\theta - k(\cos\alpha_b + C\cos\alpha_r)\sin\theta - [2HE/(t-e)](k\sin\alpha_m + E\cos\alpha_m)\}}{H\sin\alpha_b\cos\alpha_m(k\sin\alpha_m + E\cos\alpha_m)}\right) - 1\right] \quad \cdots(19)$$

ところで、被搬送物（粉粒体）を充満状態で、例えば鉛直上方向（必ずしも、鉛直でなくても良いが）に揚送させる場合、筒状ケーシング内での圧力P_Lが少なくとも正または「ゼロ」の値をとる必要がある。
【００４０】すなわち、（１７）式において、φ＝９０度を代入したP_Lの式を、下記（２０）式のように簡単に表すとともに、この（２０）式の値が正となる条件から、下記（２１）式が得られる。
【００４１】
$P_L = P_0 \times S - T \times (S - 1)$ ・・・（２０）
なお、（２０）式中、Ｓは（１７）式の右辺のｅｘｐの部分を表し、Ｔは（１７）式の右辺の第２項の前部を示している。
【００４２】ここで、$P_L \geqq 0$とすると、下記（２１）式が得られる。
$P_0 \geqq T \times (1 - 1/S)$ ・・・（２１）
ここで、（１／Ｓ）≒０であるため、下記（２２）式が得られる。
【００４３】$P_0 \geqq T$ ・・・（２２）
なお、上記（２２）式において、$P_0 = T$とした場合のグラフを、すなわちスクリュウコンベヤにおける必要加圧力を図４（条件は図中に示す）に示し、より具体的には、φが９０度である垂直軸付きスクリュウコンベヤの場合を（ａ）にて示し、同じくφが９０度である垂直リボン状スクリュウコンベヤの場合を（ｂ）にて示し、同じくφが９０度である垂直リボン状スクリュウコンベヤの中心に固定軸体が挿入された場合を（ｃ）にて示す。なお、図４の横軸が圧力を示し、縦軸が排出角θ（後述する）を示している。
【００４４】また、上記と同様の方法にて、押込用スクリュウコンベヤ６における加圧力（押込力でもあり、以下、発生加圧力という）を、（１７）式にて求めることができる。この場合、（１７）式のφは０度とされる。
【００４５】図４（ｄ）および（ｅ）に、押込用スクリュウコンベヤ６における発生加圧力を示し、特に、（ｄ）は水平軸付きスクリュウコンベヤによる発生加圧力を示し、（ｅ）は水平リボン状スクリュウコンベヤによる発生加圧力を示している。
【００４６】さらに、図４（ｆ）は、スクリュウコンベヤにおける排出角θと排出効率ηとの関係を示す曲線である。上記排出効率ηは、（スクリュウコンベヤの実排出量／スクリュウコンベヤの理論排出量）であり、下記（２３）式にて表される。
【００４７】
【数１７】

$$\eta = \tan\theta / (\tan\theta + \tan\alpha_b) \quad \cdots(23)$$

ここで、図５に、排出効率ηと被搬送物の排出角θとの関係を示す。
【００４８】図５の（ｂ）において、Ａ点の粒子がスクリュウの１回転でＡ′点に移動した場合、粒子は理論通

り１ピッチｔだけ移動したことになり、排出効率ηは１．０となる。しかし、スクリュウおよび筒状ケーシングと粒子との摩擦により、Ａ点の粒子がＢ点に移動したとすると、粒子の移動距離は、ηｔとなり、排出効率ηは１．０より小さくなる。

【００４９】このとき、粒子の排出方向は、Ａ点とＢ点とを結ぶ線上となり、スクリュウの軸心に直角な断面となす角をθとし、このθを排出角と称している。また、図５（ａ）は、スクリュウ羽根の展開図を示しており、Ａ点の粒子がスクリュウの１回転でＢ点に移動し、その方向は角度θを持つことになる。

【００５０】そして、ＡＣをスクリュウ羽根１回転の外周長さ（πD_b）とすると、$\pi D_b = \eta t (\cot\alpha_b + \tan\alpha_b)$の関係より、$\eta$は上記（２３）式にて表すことができる。

【００５１】そして、またこの排出効率ηを表す（２３）式は、下記（２４）式に示すようにスクリュウの回転数ｎで表すことができる。

【００５２】

【数１８】

$$\eta = \tan\theta / (\tan\theta + \tan\alpha_b)$$
$$= Q / \{(\pi (D_b^2 - D_r^2)/4)(t - e) n\} \quad \cdots (24)$$

但し、（２４）式は軸付きスクリュウの場合を示しており、リボン状スクリュウの場合には、同式中の（$\pi (D_b^2 - D_r^2)/4$）の部分が、（$\pi D_b^2/4$）となる。

【００５３】すなわち、上記（２４）式から、排出効率ηおよび理論排出量Ｑが分かれば、スクリュウの回転数ｎを求めることができる。但し、D_b，ｔ，ｅを、スクリュウに関する寸法であり、例えば搬送容量などに応じて、ほぼ決まっているもので、変更する場合には、排出効率ηを満足するように、回転数ｎとともに決定すればよい。

【００５４】ここで、図４に示すグラフを用いて、揚送用スクリュウコンベヤおよび押込用スクリュウコンベヤの効率的な設計方法について説明する。なお、ここでは、揚送用スクリュウコンベヤとして、軸付きスクリュウコンベヤを用いるものとし、また押込用スクリュウコンベヤとしてリボン状スクリュウコンベヤを用いるものとする。

【００５５】まず、スクリュウコンベヤの設計を行う場合、最初に、仕様に基づく理論排出量Ｑおよびその排出効率ηを、例えばQ_1およびη_1に決定（設定）する。すると、図４（ｆ）に示す排出効率ηの曲線から、ηが所定値η_1のときの排出角θ_1が求まり、このθ_1に対応する垂直軸付きスクリュウコンベヤにて必要とされる加圧力ΔＰは、その曲線（ａ）からΔP_1であることが分かる。

【００５６】すなわち、垂直軸付きスクリュウコンベヤに対して、被搬送物である粉粒体を押し込むのに必要な加圧力、すなわち押込用スクリュウコンベヤにおける発生加圧力はΔP_1より大きいことが条件であり、したがって図４（ｅ）のリボン状スクリュウコンベヤの発生加圧曲線から、ΔP_1に対応する排出効率η_2および排出角θ_2が求まる。

【００５７】このようにして求められた揚送用スクリュウコンベヤおよび押圧用スクリュウコンベヤにおける排出効率η_1およびη_2に基づき、上記（２３）式から、スクリュウ回転数n_1およびn_2が求められる。

【００５８】そして、この回転数n_1およびn_2を得られるように、スクリュウの各部の寸法を決定するとともに、回転駆動部例えば電動機を選定し、これら回転数n_1およびn_2でもって運転を行えばよい。

【００５９】この回転数n_1でもって、上述した荷役装置４のスクリュウ式搬送装置１における揚送用スクリュウ２２を運転させるとともに、回転数n_2でもって押込用スクリュウ３２を回転させれば、船倉２ａ内の粉粒体Ｊを、必要加圧力でもって揚送用スクリュウコンベヤ５側に押し込むことができ、したがって筒状ケーシング２１内で充満した状態で粉粒体Ｊを確実に揚送することができる。すなわち、従来のように、粉粒体が筒状ケーシング内で隙間を有した状態で揚送する場合に比べて、１／１０程度（例えば、５００回転程度から４０回転程度になる）の回転数でも揚送することができ、したがって搬送効率が良く、機械同士の摩耗も少なく、且つ騒音が少ないスクリュウ式搬送装置を提供することができる。

【００６０】ここで、具体的な数値を用いて、各スクリュウにおける加圧力について比較検討する。但し、比較検討する際のスクリュウの寸法は下記の通りである。

スクリュウ外径：$D_b = 1.0$

スクリュウ軸径（リボン状スクリュウ羽根の穴径）：$D_r = 0.4 D_b$

スクリュウピッチ：$t = 1.0 D_b$

スクリュウ羽根厚：$e = 0.07 D_b$

スクリュウ羽根高さ：$H = 0.3 D_b$

スクリュウコンベヤ長さ：$L = 20 D_b$

摩擦係数：$\mu_b = \mu_s = 0.5$

内部摩擦角：$\phi_i = 25°$

図４において、例えば垂直リボン状スクリュウコンベヤを、排出効率を０．３３にする場合、すなわち排出角θを９度で運転する場合は、必要加圧力P_Rは約１．３γD_bとなり、γが１．２ｔ／m^3で、D_bが０．３ｍであるときは、必要加圧力P_Rは０．００４５９ＭＰａ（１．３×１．２×０．３＝０．４６８ｔ／m^2＝０．０４６８ｋｇ／cm^2）となる。

【００６１】これに対して、垂直軸付きスクリュウコンベヤを、同様に、排出効率が０．３３で、排出角θを９度で運転する場合は、必要加圧力P_Rは約５γD_bとなり、γが１．２ｔ／m^3で、D_bが０．３ｍであるとき

は、必要加圧力P_Rは０．０１７６ＭＰａ（５×１．２×０．３＝１．８ｔ／m^2＝０．１８ｋｇ／cm^2）となり、したがって必要加圧力はリボン状スクリュウコンベヤの３．８倍となる。

【００６２】すなわち、排出効率ηを同一にした場合、垂直軸付きスクリュウコンベヤの場合、リボン状スクリュウコンベヤに比べて、大きい加圧力がないと鉛直に搬送することができないことが分かる。

【００６３】また、図４から、垂直軸付きスクリュウコンベヤの場合、排出角θが１０度を越えると、必要加圧力P_Rが急に大きくなることから、軸付きスクリュウコンベヤでの排出角θは１０度付近が経済的上限であると考えられ、このときの排出効率ηは、０．３６である。

【００６４】一方、リボン状スクリュウコンベヤおよび中心に固定軸体が挿入されたリボン状スクリュウコンベヤでは、排出角θが１５度を越えると、必要加圧力P_Rが大きくなり、排出角θが２０度付近が経済的上限であると考えられる。このときの排出効率ηは０．５４である。

【００６５】このような揚送用スクリュウコンベヤ（垂直軸付きスクリュウコンベヤの例以外では）においては、排出効率ηが０．１～０．６（排出角θでは、２度～２５度の範囲）の範囲で運転するのが好ましい。

【００６６】次に、押込用スクリュウコンベヤについて、具体的数値を用いて説明する。押込用スクリュウコンベヤにおいては、その加圧力P_Lが、揚送用スクリュウコンベヤの必要加圧力P_Rより大きくなるような運転が行われる。

【００６７】図４において、垂直リボン状スクリュウコンベヤの排出角９度における必要加圧力と同一の加圧力で、中心部に固定軸体が挿入されたリボン状スクリュウコンベヤを運転すると、垂直リボン状スクリュウコンベヤの排出効率ηが０．３３であるのに対し、このときの必要加圧力を発生させる中心部に固定軸体が挿入されたリボン状スクリュウコンベヤにおける排出効率が０．４２となり、中心部に固定軸体が挿入されたリボン状スクリュウコンベヤの方が排出効率が良いことが分かる。

【００６８】また、垂直軸付きスクリュウコンベヤを９度の排出角θで運転するときの必要加圧力を発生する水平軸付きスクリュウコンベヤでは、排出角θが１１度で、排出効率ηが０．３８であるのに対し、水平リボン状スクリュウコンベヤの場合は、排出角が２５度、排出効率が０．６で、垂直軸付きスクリュウコンベヤの必要加圧力を満足することになる。このことは、水平リボン状スクリュウコンベヤの小型化を図り得ることを意味している。逆に、垂直リボン状スクリュウコンベヤを排出角が約２３度、排出効率が約０．６で運転することもできる。また、中心部に固定軸体が挿入されたリボン状スクリュウコンベヤを排出角９度で運転する場合には、排出角θが４０度で、排出効率ηが０．８となり、中心部に固定軸体が挿入されたリボン状スクリュウコンベヤでは、さらに効率のよい運転をすることができる。

【００６９】ところで、上記実施の形態においては、揚送用スクリュウ２２として軸付きスクリュウを説明したが、リボン状スクリュウまたは中心部に固定軸体が配置されたリボン状スクリュウであってもよく、さらに押込用スクリュウ３２としてリボン状スクリュウを説明したが、軸付きスクリュウであってもよい。

【００７０】さらに、上記実施の形態に係るスクリュウ式搬送装置においては、図２に示すように、ほぼ鉛直方向で配置された揚送用スクリュウコンベヤ５に被搬送物を水平方向で押し込むための水平押込用スクリュウコンベヤ６を１台設けたが、例えば図６に示すように、水平方向で押し込む押込用スクリュウコンベヤ６Ａと、揚送用スクリュウコンベヤ５との間に、斜め上方向で押し込む傾斜押込用スクリュウコンベヤ６Ｂを設けるようにしてもよい。

【００７１】すなわち、被搬送物と筒状ケーシングおよびスクリュウとの間の各摩擦係数μ並びに被搬送物の比重γが大きくなった場合には、揚送用スクリュウコンベヤ５内での圧力がゼロ以上（P_L≧０）となるようにするための押込圧力P_0が過大となるが、上述したように、押込用スクリュウコンベヤを二段に配置することにより、このような過大な押込圧力に対処することができる。

【００７２】また、傾斜押込用スクリュウコンベヤ６Ｂは揚送用スクリュウコンベヤ５に対して可動継手５１を介して、また水平押込用スクリュウコンベヤ６Ａは傾斜押込用スクリュウコンベヤ６Ｂに対して可動継手５２により、それぞれ揺動自在に連結されるとともに、各スクリュウコンベヤ５：６Ｂ，６Ｂ：６Ａ間には、互いの姿勢調整用のシリンダ装置５３，５４が設けられて、被搬送物のいかなる積み出し姿勢（積出し状態）にでも対処し得るように構成されている。

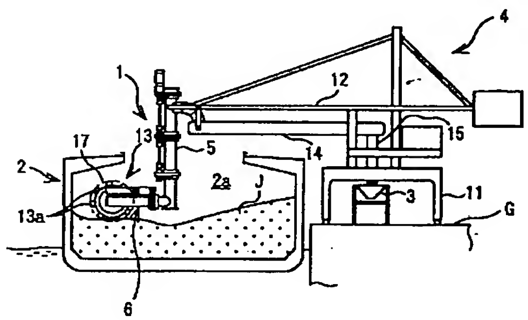
【００７３】

【発明の効果】以上のように本発明のスクリュウ式搬送装置の設計方法によると、被搬送物が充満された状態の筒状ケーシング内の圧力を表す計算式から得られるスクリュウでの必要加圧曲線から、所定の排出効率に対応する揚送用スクリュウコンベヤにおける必要加圧力を求めるとともに、排出効率曲線からスクリュウの回転数を求め、そしてこの必要加圧力を越える押圧力でもって押圧用スクリュウコンベヤを駆動させることにより、被搬送物を充満させた状態で揚送を効率良く且つ確実に行うことができる。すなわち、従来のように、筒状ケーシング内で隙間を有した状態で被搬送物を揚送する場合に比べて、低速回転でもって揚送することができ、したがって搬送効率が良く、機械同士の摩耗も少なく、且つ騒音が少ないスクリュウ式搬送装置を提供することができる。

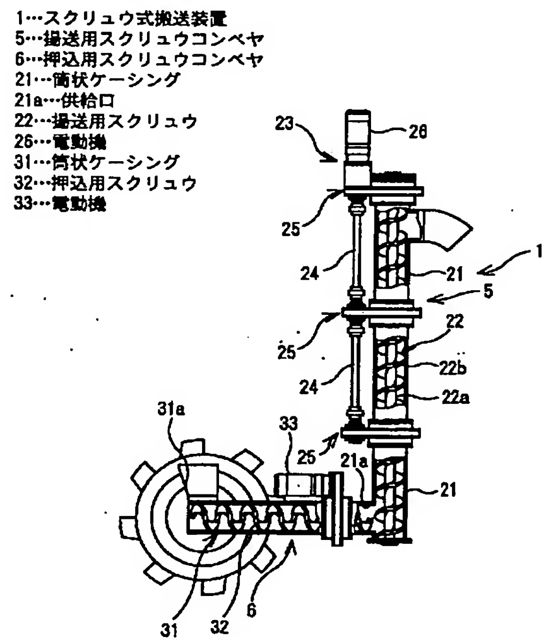
【図面の簡単な説明】

【図１】本発明の実施の形態におけるスクリュウ式搬送装置の使用状態を示す側面図である。
【図２】同スクリュウ式搬送装置の断面図である。
【図３】同スクリュウ式搬送装置の筒状ケーシング内での圧力を求めるための原理を説明するスクリュウの要部拡大図である。
【図４】同スクリュウ式搬送装置の各筒状ケーシング内での必要加圧曲線および発生加圧曲線並びに排出効率曲線を示すグラフである。
【図５】同スクリュウ式搬送装置における排出効率と排出角との関係を説明する図である。
【図６】同スクリュウ式搬送装置の変形例における使用状態を示す側面図である。
【符号の説明】
１　　スクリュウ式搬送装置
５　　揚送用スクリュウコンベヤ
６　　押込用スクリュウコンベヤ
２１　　筒状ケーシング
２１ａ　　供給口
２２　　揚送用スクリュウ
２６　　電動機
３１　　筒状ケーシング
３２　　押込用スクリュウ
３３　　電動機

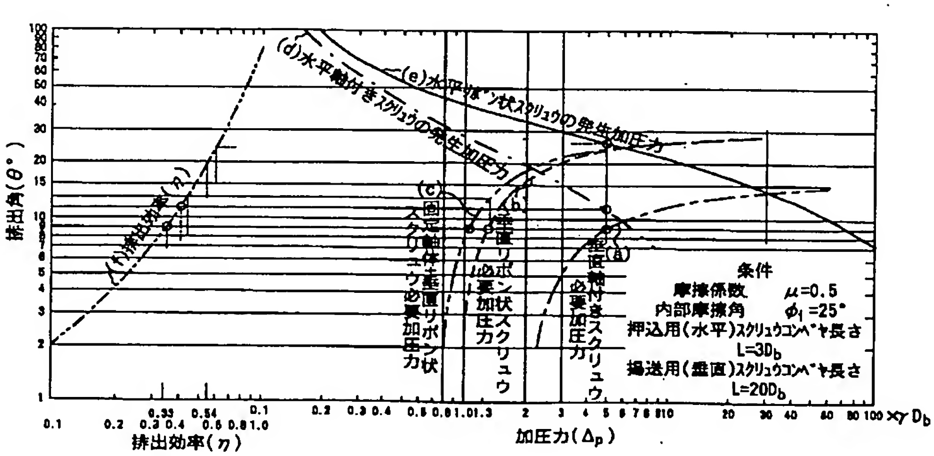
【図１】



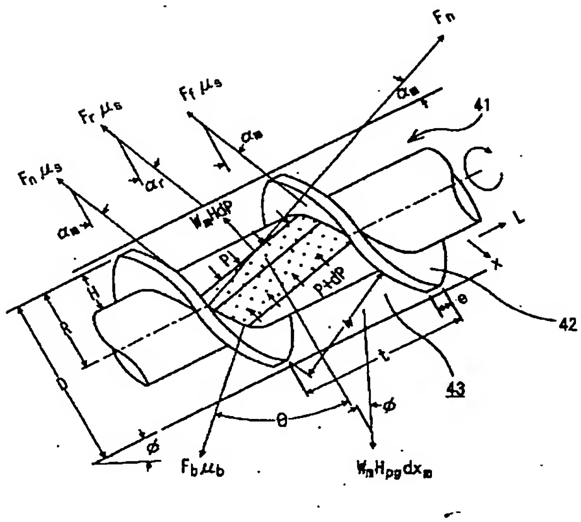
【図２】



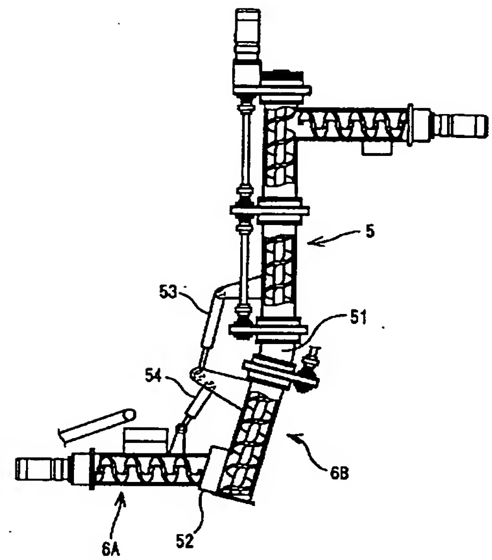
【図４】



【図３】

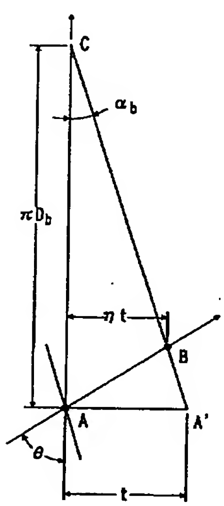

Fn
Fn μs
Fr μs
Ft μs
41
42
43
L
x
H
R
D
P
P+dP
t
e
θ
φ
Fb μb
αr

【図６】

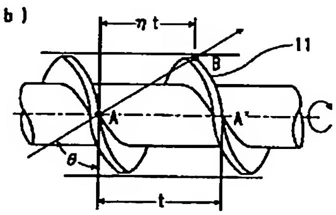

5
53
51
54
6B
6A
52

【図５】

（ａ）


C
αb
πDb
ηt
B
A
A'
θ
t

（ｂ）


ηt
11
B
A
A'
θ
t